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Varying the Gradient Pulse Length Gives Valuable Information in NMR Diffusometry

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1. Introduction

NMR diffusometry has evolved to become one of the most important methods in the study of diffusion and flow of liquids in complex material. Material that may be investigated spans a broad range: From rocks to soft biological material. In the latter case, one is often faced with a problem of trying to separate effects from inhomogeneities and restrictions. In the former case, we mean a situation where the liquid has a diffusion coefficient that depends on position in the sample, due for instance, to differences in concentrations/densities across the sample. Moreover, the length over which these inhomogeneities persist must be longer than the Mean Square Displacement of the liquid during the diffusion time (i.e. the distance between the gradient pulses). In the latter case, we assume barriers, reflective or semipermeable, such that the diffusion is no longer Gaussian. Both of these effects give rise to curvature in Stejskal-Tanner plots. We present here an approach that allows one to separate these effects by making use of information conveyed from the variation of the gradient pulse length.

2. Results and discussion

The results of NMR diffusometry experiments are conveniently analysed by the *q*-space approach [1]. The master equation used relies on the gradient pulses being infinitely short: The so-called Short Gradient Pulse limit. In reality, the condition for this limit is seldom reached. This can be seen from the fact that the gradient pulse length affects the echo decay curves for systems where the diffusion is not Gaussian, under conditions of constant gradient pulse area.

An example is given in Figure 1, where we show Stejskal-Tanner plots for a gel emulsion where the effects are in fact quite marked [2]. This can be used to an advantage since it suggests one more parameter, besides the diffusion time, that can be varied in a NMR diffusometry experiment. We will show in this contribution how this approach is used to investigate diffusion in a "simple" model system, namely that of common baker's yeast.

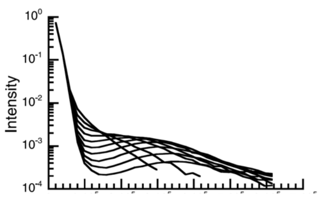

Figure 1. Stejskal Tanner plots from water in a gel emulsion. The gradient pulse length is varied from 1.5 to 50 ms. under conditions of constant gradient pulse area.

3. Conclusion

We have shown how the variation of the gradient pulse length in addition to the more common variation of the diffusion time provides an extra, important dimension in the study of liquid diffusion in complex material. We suggest that this will be a valuable tool not only in NMR diffusometry but also in MRI diffusion weighted images.

References

[1] P. T. Callaghan, Principles of Nuclear Magnetic Resonance Microscopy; Clarendon Press: Oxford, 1991.

[2] C. Malmborg, D. Topgaard, O. Söderman, J. Magn. Reson., 169 (2004) 85-91.